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Application of Hypo and Hyperbaric Chamber in Czech Air Force

LtCol. DOŠEL Petr, M.D., LtCol. SÁZEL Miloš, M.D., Ph.D.

Institute of Aviation Medicine
P.O.BOX 19
160 60 Prague 6
Czech Republic

Tel.: +420 2 20218118
Fax.: +420 2 24311945
E- mail: petrdosel@atlas.cz

Summary: The paper provides an overview about using of hypo and hyperbaric chambers at IAM Prague and about hyperbaric oxygen therapy (HBO) indications. Otoscopy and impedance tympanometry are pursued routinely on the instant before all expositions. The pilot's status is monitored by method of pulse oxymetry during all hypoxic tests and demonstrations. The %SpO₂ monitoring provides the most valid longitudinal information about clinical status of examined pilots during hypoxia load. The therapy benefit during HBO is evaluated using transcutaneous oxymetry (%PtcO₂) in the case of peripheral defects of tissue. It is necessary to achieve %PtcO₂ values about 350 – 400 mmHg for successful therapy of tissue defects of the lower extremities.

The complex of three hypobaric and one hyperbaric chambers was installed at the Institute of Aviation Medicine in Prague in 1965. All chambers are routinely utilised for medical examinations, training and other needs of civilian or military pilots and other crew members. All hypo and hyperbaric chambers were rebuilt and redeveloped last year. Modification of our training system to standard STANAG 3114 and increasing of safety of operation were main reasons of that.

Medical status evaluation of each pilot precedes the hypobaric and hyperbaric expositions. Examined persons are fit for exposition providing that the conclusions of all clinic examinations (internal, ENT, ophthalmology, neurology, surgery, basic laboratory etc.) are normal.

We pursue routinely otoscopy and impedance tympanometry on the instant before all expositions. It is necessary to disqualify all events of Eustachian tube block. Otoscopic finding of eardrum's retraction or shift of the top of the tympanometric curve within zero zone (the pressure before and behind of the eardrum are not equal) means unfit for exposition. We use the Hand Tymp 3000 Danplex. It is portable battery operated tympanometer designed for quick and precise screening and diagnosing of the basic functions of the middle ear. Very important is quantification of compliance peak of the tympanic membrane. Compliance peak below -30daPa and peak more than +30 daPa presents most frequently low pressure or overpressure in the middle ear as a consequence of poor Eustachian function. Tympanometric curve without compliance peak presents reduced mobility of the tympanic membrane (perforation), wax lump, otosclerosis, otitis media etc. Examination makes possible to select pilots with probable troubles during exposition. In our opinion it is necessary to do this examination before each hypo and hyperbaric exposition especially if the gradient of the pressure change is high. We observe the dysbarisms in 10% of patients. The most frequent symptoms are pain of eardrums, pain of frontal and paranasal sinuses, nosebleed and pain of abdomen.

HYPOBARIC CHAMBERS

Single, three and thirteen seated hypobaric chambers are located at the IAM. Technical facilities of all hypobaric chambers enable to climb up to 127 000 feet using variable defined velocity of ascent and following descent. The chambers are used for following tasks:

- I. selection of pilot's applicants,
- II. initial and periodic aeromedical training of the Czech Air Force pilots and cadets,
- III. evaluation of pilot's flight ability during his/her professional career,
- IV. special exposures (high parachute jumping etc.),
- V. expertise aims (oxygen devices and systems qualification etc.).

I. Selection of pilot's applicants

The clinical examination complex is the base of pilot applicant's selection at the IAM. We do the hypoxia tolerance examination if the applicant's general efficiency is not quite convincing. The applicant is then exposed to hypobaric chamber test at the level 16 400 feet. Duration of the test is 20 minutes. Velocity of ascent and descent is 55 feet.s⁻¹.

II. Initial and periodic aeromedical training of Czech Air Force cadets and pilots

A. Cadets:

1. First year of the academy

Each cadet has to undergo an exposure to reduced pressure in hypobaric chamber to a simulated altitude of 16 400 ft. Duration of a hypoxic exposure is 20 minutes. Velocity of ascent and descent is 55 feet.s⁻¹. Evaluation of visual potency in defined hypoxic conditions is the aim of that examination. Cadets perform simple ophthalmological tests during hypoxic part of examination - contrast vision, colour vision, stereoscopic vision etc.

2. Third year of the academy

- a) Each cadet has to be exposed to hypoxia demonstration at 25 000 feet level. Velocity of ascent and descent is 160 feet.s⁻¹. The profile of exposition is similar to Type 37 Chamber flight USAF but it is integrated with a higher velocity of decompression (980 feet.s⁻¹) from 8 000 feet to 25 000 feet. Duration of a hypoxic exposure is 5 minutes maximally. The change of colour vision is demonstrated at the level of 18000 feet subsequently.
- b) The test of tolerance to the pressure changes precedes Rapid Decompression Exposition. Parameters of that test are following: decompression from 8000 feet to 25 000 feet, ascent velocity is 1400 feet.s⁻¹.
- c) The Czech Air Force Rapid decompression is similar to Rapid decompression test in RAF or USAF including the ear and sinus check. Mentioned above exposition is characterised by rapid drop of atmospheric pressure from the level 8000 feet to 25 000 feet. Ascent velocity is 1400 feet.s⁻¹. Denitrogenation (30 minutes) precedes all mentioned expositions.

B. Pilots

- a) Flight personnel have to attend a continual training every fifth year. Pilots are exposed to the hypoxia tolerance test and rapid decompression. Parameters of tests are equal to mentioned above cadet's tests.
- b) PPB (positive pressure breathing) training (41 000 feet). Pilots of combat aircraft train positive pressure breathing when finishing their basic flying training. The first part is accomplished in the simulator on the ground. The level of the oxygen positive pressure is 30 mmHg. The second part is accomplished in the hypobaric chamber. The pilot "climbs" to altitude 41 000 feet (positive pressure 30 mmHg intrapulmonary). Duration of the load is 2 minutes. Velocity of the climb is about 1 604 feet.s⁻¹. Velocity of descent is as possible as maximal. Former method of PPB training involved climbs up to the level 52 500 and 82 000 feet in hypobaric chamber.

III. Evaluation of pilot's flight ability during his/her professional career

Pilot's flight ability is usually evaluated after treatment of various serious sickness or more frequently during convalescence period. The degree of the load depends on the clinic status. We use generally hypoxia examination at the level 16 400 feet or 25 000 feet. These methods were described in previous paragraphs. Pilot's flight ability after ENT illness is evaluated using test of tolerance to pressure changes. It means a climb to the altitude 13 000 feet. Gradient of ascent is 98 feet.s⁻¹ and descent 50 feet.s⁻¹. We can do the tympanometric examination in the case of necessity during the load and we do it routinely after finishing of that test.

IV. Special exposures

Special exposures up to 37 700 feet without PPB and above that level with PPB. Ascent and descent velocity depends on circumstances or requirements. These expositions are doing for example by reason of

evaluation of mountain-climber's hypoxia tolerance, test work of a new oxygen equipment, high altitude parachute jumping training etc.

We monitor the pilot's status by method of pulse oxymetry during all hypoxic tests and demonstrations. We use hand held pulse oxymeter Nonin 8500 M. That device makes possible to monitor the level of oxygen saturation of capillary haemoglobin continuously, to storage of measured data and to print it as a table or diagram.

The relationship between haemoglobin oxygen saturation and psychophysiological ability is evaluated. We count %SpO₂ decreasing below 60 critical and in this case we supply the oxygen for the pilot immediately.

Our actual experience shows that it is possible to select pilots with a low hypoxia tolerance during the third minute at the level 25 000 feet (Figure 1). The statistical significant difference of %SpO₂ is 68 % opposite 62 % in the group of volunteers with insufficient tolerance. The difference of these values increases progressive and a lot of volunteers with low tolerance have to finish before the 5th minute of the test. The %SpO₂ recovery of all pilots after oxygen breathing initiation is very prompt (up to 1 minutes to the value 98% at all pilots) and without significant difference (Figure 2). The critical value 60% of %SpO₂ is correct and signalises a drop of psychical efficiency very well. We suppose that the monitoring of %SpO₂ provides the most valid longitudinal information about clinical status of examined pilots during hypoxia load.

HYPERBARIC CHAMBER

Five seated hyperbaric chamber is located at the IAM. Dimensions of the cylindrical chamber are: length - 4 m, diameter - 2 m. Technical facilities of chamber enable to increase the pressure up to 1 MPa using variable defined velocity of descent and following ascent. The chamber is used for following tasks:

I. Hyperbaric oxygen therapy

Hyperbaric oxygen therapy (HBO) exposition is defined by air pressure 0,3 MPa in the chamber. Patients breathe oxygen from oxygen masks during 120 minutes. Duration of the compression is 15 minutes in average. That time depends on patients' ability to tolerate the pressure change. Oxygen breathing is interrupted for 5 minutes after 1 hour of exposition as a oxygen toxicity prevention. The decompression phase is interrupted twice at 6 and 3 meters for 5 and 10 minutes. HBO method is usually used at the IAM Prague in following indications:

a) Absolute indications:

- anaerobic clostridial infection,
- decompression sickness,
- air emboli,
- CO and CN⁻ poisoning .

b) Relative indications:

- peripheral circulatory insufficiency,
- diabetic microangiopathy,
- gangrene,
- refractory cutaneous defects,
- trombagitis obliterans and other vasculitis,
- crural ulcer,
- chronic bone infection,
- acute hypacusia, acutrauma, Menier disease, tinnitus, vestibular dysfunction etc.

Over 120 patients are treated by oxygen in hyperbaric conditions in our pressure chamber every year. The spectrum of patients is in fact more wide than I mentioned. Nevertheless, ischaemic status of a limb or an inner ear is the most frequent indication of HBO application. This involves about 80% of our outpatients. The number of HBO expositions depends on diagnosis, patient's clinical status, therapeutic response etc. and it fluctuates from 5 to 50 expositions.

We evaluate the therapy benefit using transcutaneous oxymetry (%PtcO₂) in the case of peripheral defects of tissue. This method is also used for selection of candidates for HBO therapy by identifying the

presence of tissue hypoxia. We use the Kolormon MC 7250-700 unit (fy. Kontron Instruments). An electrode is usually located on a tarsus or on a crus. The %PtcO₂ values are monitored continuously during all expositions.

We concentrated on comparison of %PtcO₂ values between normal and ischaemic tissues of the lower extremities last year. We demonstrated the significant difference of %PtcO₂ between the healthy and ischaemic tissues during HBO. The %PtcO₂ values rise during HBO eight to ten times in the case of normal tissues opposite five to six times increasing at patients with insufficient blood circulation. The %PtcO₂ absolute values enhance from 65 to 650 mmHg at healthy tissues opposite 60 to 360 mmHg at ischaemic tissues. The course of %PtcO₂ changes during HBO are presented in Figure 3. Both curves of %PtcO₂ changes also manifest the significant increase of oxygen supply of peripheral tissues during HBO.

Our experiences show that it is necessary to achieve %PtcO₂ values about 350 – 400 mmHg for successful therapy of tissue defects of the lower extremities. If the %PtcO₂ value is less than 200 mmHg the therapy will be probably unsuccessful.

II. Test of tolerance to the oxygen

This test represents a basic evaluation of risk of oxygen toxicity. Divers are exposed to the pressure 0,3 MPa and they have to breathe oxygen for 15 minutes without any troubles.

III. Test of tolerance to the pressure changes

Divers are exposed to the defined level of pressure (up to 1 MPa).The scheme of decompression depends on the level of pressure and duration of exposure and corresponds to a decompression table.

Figure 1

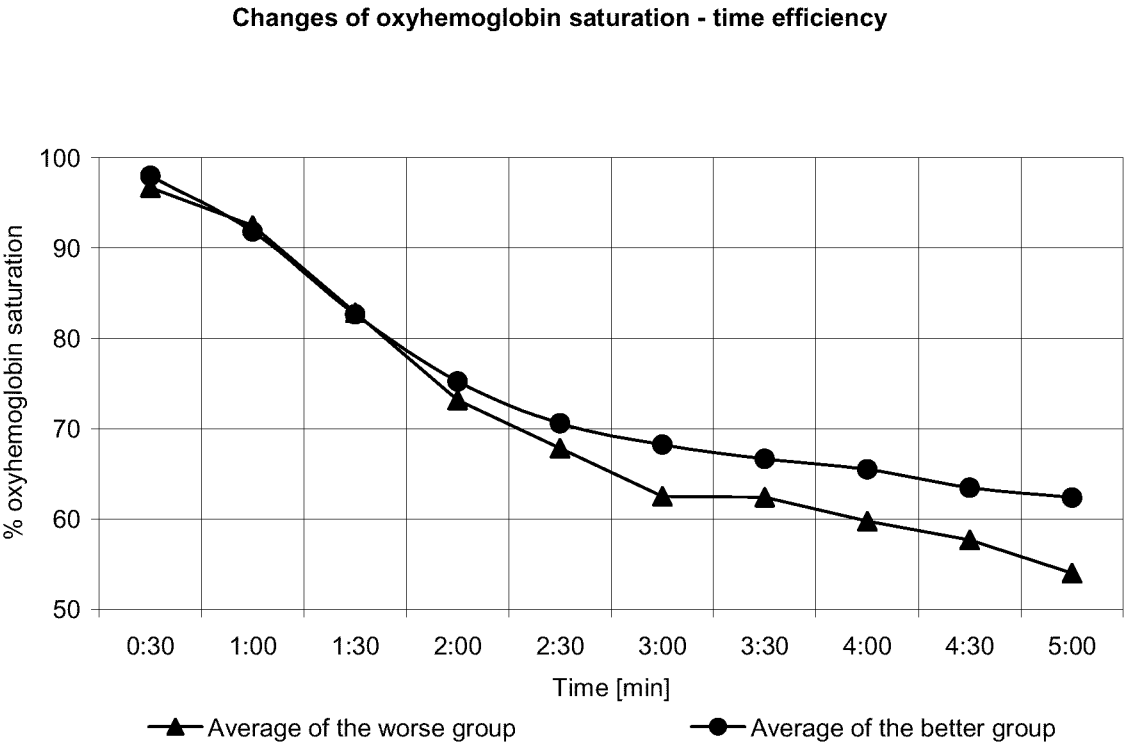


Figure 2

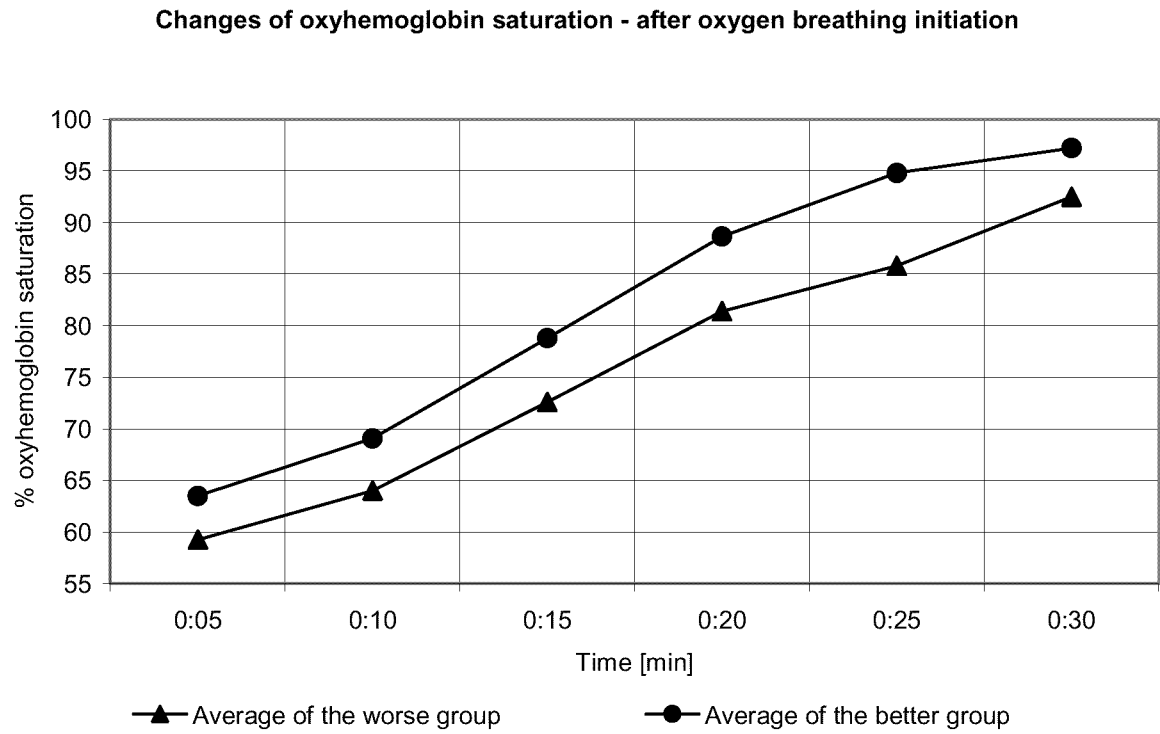
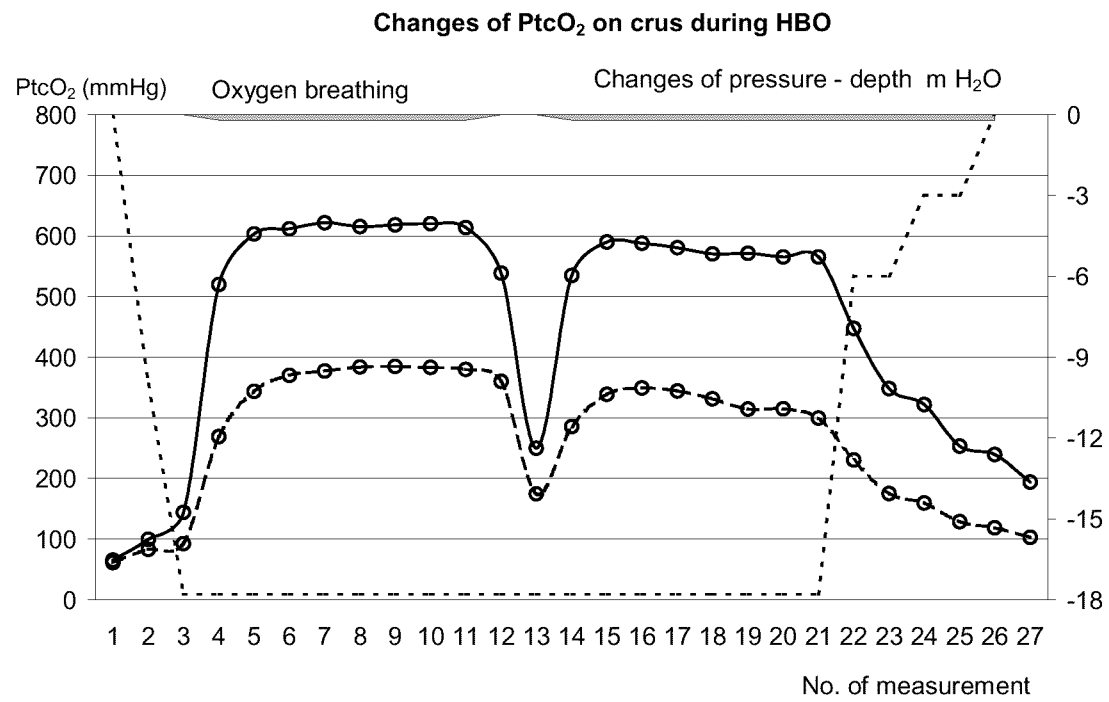


Figure 3



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